The European B2B Forum for the Electronics Industry

EDIFICE White Paper

Radio Frequency Identification (RFID)

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1 Introduction

The “EDIFICE RFID white paper” provides awareness of the RFID technology and is intended to people who have no or little experience with the technology.

The document gives advice on what has to be considered in the conception phase of a RFID project and provides operational aspects.

The EDIFICE RFID white paper could be regarded as an overview manual, which summarizes the aspects, which should be taken into consideration, for making the decision on a RFID-project.

2 RFID Technology

2.1 Overview

The RFID technology is not a “new” technology. RFID applications have been in existence for more than a decade in one-chip configurations and even longer in less integrated technology. Common well known and proven applications that use Radio Frequency technology include:

- Contact less cards used for control of access to buildings and other secure areas
- Electronic tolling for roads
- Automatic ticketing systems
- Animal identification

RFID is gaining more publicity today based on that the realization of the technology has the potential to improve supply chain processes. Published pilot projects, e.g. within Wal-Mart, Metro and US Department of Defense (DoD), have opened up for the awareness of the RFID technology in general, and this has led to the current interest in RFID. With this interest, the Research and Development activity around RFID has increased as well as international standardisation. As a result of this, there are many commercially available RFID hardware and software solutions on the market.

There are also pressures by DoD and other agencies to explore RFID and other technologies such as automatic identification technologies using 2D symbols (i.e. Data Matrix) to improve unique item identification.

2.2 A typical RFID system

A typical RFID system comprises a tag (carrier of data), a writer (store data), a reader (receiver of data) and an application (software/database) that is to act on the information.

Typically a writer/reader has to be connected to a host application, especially if multiple writers/readers are used to store and capture tag data at different locations. Depending on the usage requirements, the infrastructure can vary, however the principles remain the same. Typically a tag is allocated some information through a writer at one location, attached to an item, and this information is captured by a reader at another location.

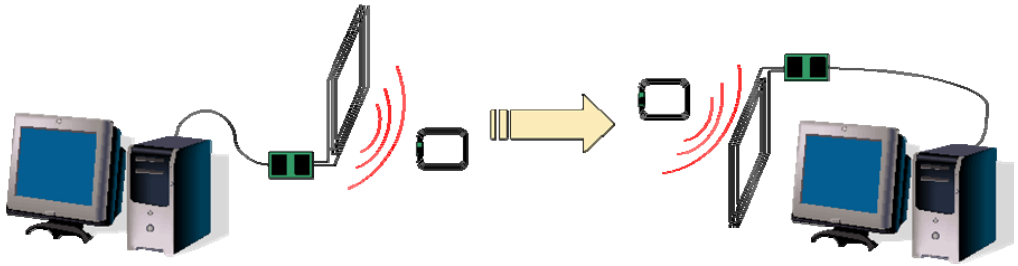

Figure 1 – Illustration of a RFID system

An example of an information (process) flow based on figure 1 could be as follows:

1. Information for an item present in an application is stored in a tag (placed at the item) by a writer at 'Location A'.
2. The item is then moved from 'Location A' to 'Location B'
3. At 'Location B' the tag is identified by a reader and the information in the tag is captured by the reader and then the application at location B acts on the received information.

2.3 Frequencies for RFID

The frequency and parameters at which the tag communicates with the writer or reader are also variables that are to be considered in the overall design of a RFID system. Allocation of frequencies and related requirements on these are in general managed in 3 regions (defined by ITU) but in some cases even within single countries. An implementation must therefore be done based on existing regulation of the area where the RFID system is to be used. There exist a number of frequencies that can be used for RFID and those are standardized under ISO/IEC 18000, Information technology – Radio frequency identification for item management. The common frequencies defined by these standards for item management are:

- <135kHz (Low Frequency - LF), ISO/IEC 18000-2
- 13.56MHz (High Frequency - HF), ISO/IEC 18000-3
- 433MHz, ISO/IEC 18000-7
- 860-960MHz (Ultra High Frequency), ISO/IEC 18000-6
- 2.45GHz (Microwave), ISO/IEC 18000-4

Most commonly used frequencies for item identification – supply chain management are High Frequency (HF) and Ultra High Frequency (UHF).
As every frequency has different physical properties, not every air interface is practical for use under all circumstances and has to be evaluated based on the type of application. For example:

- UHF is sensitive to water, high humidity and metal surfaces which absorb higher frequencies.
- HF is not that sensitive in these environments.
- UHF offers greater reading distances and faster reading speed, if the conditions are properly set.

2.4 Components of a RFID system

2.4.1. Tag

The tag (active or passive) is one of the more important components within the RFID system, since the information about an item to be identified is contained within the tag. Depending on decision of tag type to be used, a large extent of the rest of the infrastructure in a RFID system is determined.

Tags basically consist of a chip and an antenna which are 'packaged' in a wide variety of sizes, shapes (e.g. flat, square, round, cylindrical etc) and materials (e.g. plastic, ceramic, glass etc).
Most of the tags (both passive and active) use the 'Reader Talks First' principle, meaning that the tag requires an external signal from a writer/reader to be activated and only a small number of tags uses the 'Tag Talks First' principle that actively sends out a signal that is captured by a writer/reader.

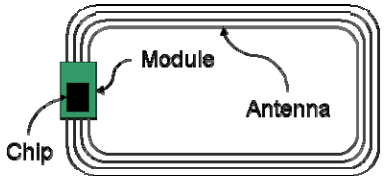

Figure 2 – Illustration of a passive tag

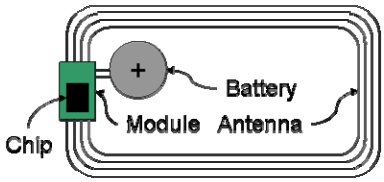

Figure 3 – Illustration of an active tag

Passive
Typically, a passive tag (figure 2) is made up of a module and an antenna packaged as an inlay in a tag casing. The module is the physical carrier of an integrated circuit (IC) and it is the module that connects the IC to the antenna. The IC is the home of the data. The antenna is the interface to the reader and therefore to the outside world. Figure 2 shows a typical tag using a module and an antenna.

The power in a passive tag is derived from an electromagnetic field by the antenna when brought in proximity to the tag. This electromagnetic field needs to create sufficient energy to 'wake-up' the tag and open up the communication channel between the tag and reader.

Active
An active tag (figure 3) has an internal power source which is used to power an integrated circuit and generate the outgoing signal independent from the power of the 'external' electromagnetic field. It may have longer range and larger memories than a passive tag and higher ability to store additional information. Figure 3 shows a typical tag using a module, an antenna and a battery. The power in an active tag is coming from the battery. The electromagnetic field is needed to initiate 'wake-up' of the tag, and by this open up the communication channel between the tag and reader.

Semi-Active
Semi-active tags use a battery to power the microchips circuitry and communicate with any sensors that are connected, but use reader power for communication with the reader.

Passive tag:	Active tag:	Semi-Active tag:
has practical read distances up to 3 meter	has practical read distances above 10 meters	has practical read distances above 10 meters
is in general small in size	has limitations in smallest size (if change of battery should be possible)	has limitations in smallest size (if change of battery should be possible)
is more suitable for tagging individual items	is not adequate for use on items of low value	is more suitable for tagging individual items, requiring long read range
is beneficial for items of low value and complexity	is beneficial for intelligent applications (i.e. data logging of temperature, pressure, etc)	is beneficial for items of medium to high value and complexity, including data logging from sensors
needs a writer/reader for activation	in most cases activated by either a reader and in some limited application identifies itself to a writer/reader	needs a writer/reader for activation
Mostly Read Only but also Read Write	Mostly Read Write but also Read Only	Mostly Read Write but also Read Only
Lower cost	Higher cost	Semi-active tags are priced between passive and active tags.
Unlimited lifetime	battery life of up to 10 years	battery life of up to 10 years

2.4.2. Reader and Writer

The reader and writer within the RFID system is typically built up of a reader module and an antenna. The reader module is connecting the antenna with the host application and consists of a radio frequency (RF) module, which generates the RF field that enables communication with a tag, and a control module, which is the interface to the surrounding components (e.g. PC). Depending on the type of RFID system the reader/writer can exist with an internal or external antenna for mobile or stationary use. Readers/Writers are designed in various shapes and sizes, depending on the requirements. There are handheld readers, mounted readers and stationary readers.

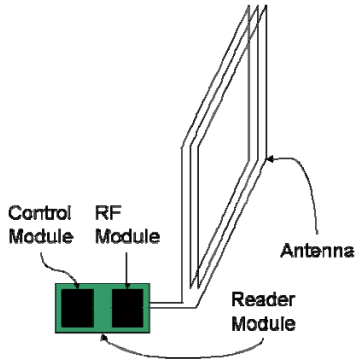

Figure 4 – Illustration of a reader

2.4.3. Host application

The host application is the environment to which the writer or reader shall be connected and that is also the component that initiate storing of data into a tag and is to act on the received information when a reader has identified a tag (within the read range of the readers antenna). This could be a stand alone PC or a company's business application depending on what the RFID system is intended for and should support. Depending on the type of tag used in the RFID system, the application could link information to a unique tag ID or initiate storing information into a tag.

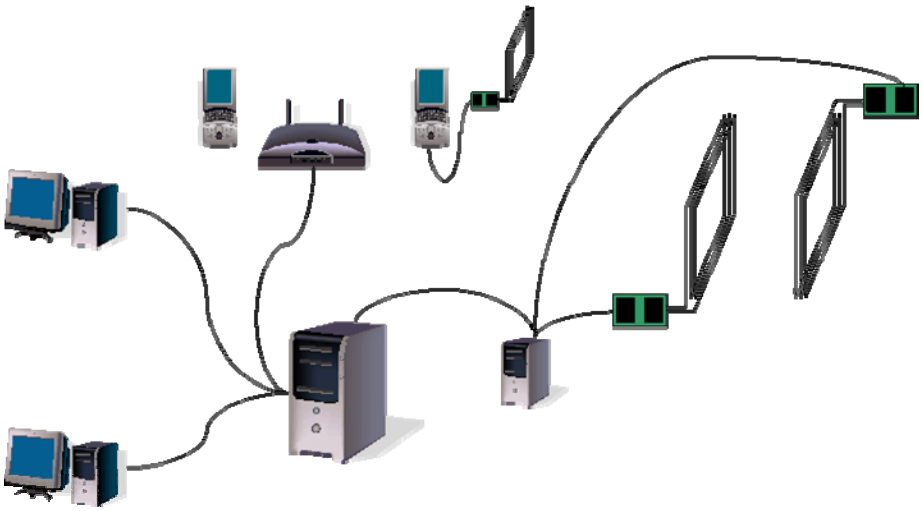

Figure 5 – Illustration of host application connected to mobile and stationary reader

2.4.4. Sensors and actuators

Sensors and actuators are often part of a RFID system.
Sensor detects event – actuators trigger an action based on sensor registration (opens door, activates light,…)
An example of a sensor used with a RFID tag is a temperature sensor applied to a blood bag which sends a signal to the attached tag if the temperature has exceeded a certain, predefined limit.
An example of an actuator is a light signal that indicates to proceed with a process after a good RFID read and after validation of the data in the process.

3 RFID/Barcode Comparison

Both RFID and barcode are automatic identification technologies that enable automated processes and improve overall operational control and management.
Implemented properly it:

- improves resource efficiency
- eliminates human errors
- speeds up processes

Barcode technology relies on "line of sight" between the barcode (carrier) and the scanner (reader), meaning that the barcode must be visible to the scanner. On the other hand RFID does not rely on "line of sight", meaning that the RF Tag (carrier) can be invisible to the reader. This is because RFID is a radio frequency based identification

system which transmits information from a RF Tag on demand to a reader using radio waves that can (with some restrictions) penetrate packaging materials.

Barcodes can be etched or printed on products or applied via labels (see Figure 6)
RFID tags need to be 'packaged' before they are attached to the product
Packaging means to embed the antenna and the micro chip into some solid material (e.g. layers of paper, plastic housing…) (see Figure 7)

Figure 6 – Example of linear barcode and 2D symbology

Figure 7 – Example of RFID tags

The following table shows the differences between Barcode and RFID.

Barcode (Linear or 2-D)	RFID
A Barcode is printed and can therefore not be modified unless a new barcode is reproduced.	Read/Write RFID tags can be reprogrammed (tag data can be appended, modified, deleted).
Simultaneous reading is not feasible.	Several tags can be read simultaneously.
Barcode reading requires line-of-sight contact between the reader and the barcode	RFID tags do not require a direct line-of-sight contact. Identification is independent of the position and arrangement of the tags. Tags can be read through wood, plastic and a lot of other materials except metal; the tag can be hidden.
A lot of inexpensive goods are not uniquely identified.	Tags can uniquely identify the products. For example, each bottle in a pack has a unique Electronic Product Code (EPC).
The barcode label space is limited.	Tags can retain a lot of additional functions (e.g. control, write/read) and a large amount of information. Several kilobytes of data can be stored by special tags.
Barcode scanners and the label need a rather clean environment	Effective in dirty environments, around chemicals, moisture and high temperatures. Not for UHF which is sensitive to humidity. For details see section 2.3
Barcode technology is very commonly used across industries because of its maturity and proof of quality.	RFID is a more recent technology. For Supply Chain management the technology is still in the process of ongoing standardisation and harmonisation.

4 Benefits of RFID

Some of the benefits of RFID can be categorized as follows:

Service / process improvement

- If properly implemented, RFID can be fast and reliable
- Increase differentiation and competitive advantage – Manufacturers need to quickly incorporate RFID to respond to retail mandates..
- Higher resiliency to many environmental impacts (humidity, temperature, mechanical, …)
- Allows for innovation and improvement of processes e.g. inventory control, cycle time improvement
- RFID does not require physical sight or contact between reader / scanner and the tagged item.
- Ability to read multiple items at any time and at high speed.
- Increase supply chain visibility
- Tags can be connected to sensors to improve quality control by monitoring e.g. temperature, humidity, shock
- For specific applications i.e. read/write tags : capable of dynamically adapting to rapid and unpredictable changes in supply or demand, unexpected moves by the competition.

Cost savings

- Labour savings by reducing or eliminating manual scanning.
- Increase Productivity and efficiency by eliminating manual data entry
- Error reduction
- Maximum control over assets – track expensive assets at any point in time

Security

- Electronic sealing with RF tags can prevent theft
- Item tagging can prevent fraud and counterfeiting

Environment

- Reusable tags cater more for the environment

5 Considerations

5.1 Business case

This depends on the type and size of application and figures can change over time. Therefore it is difficult to give appropriate figures for the listed cost elements that have to be taken into account when calculating the overall cost.
Major cost elements are: hardware (readers, transponders), software and services.

Business case factors to consider:

- Competitive advantage can be gained by those companies that look at a business case derived from problem solving, process reengineering and providing better service to their customers.

- Spend as much time as you can in the design and test phase to work out the issues. This includes the opportunity to extend your business process reengineering into your customer or suppliers environment

- Human Aspects

  It is very important to take the human aspects into consideration, while planning a RFID project. It is essential to involve all related parties and partners in the first project steps.

  On one hand, all relevant partners from development, logistics, IT, etc. should be engaged into the conception phase for obtaining a successful project.

  On the other hand, it is also important, to inform all employees about the project, in order to avoid fears or panic about job security. All employees should be informed on the implications and the consequences of the use of RFID for the processes and their work, the expected advantages and disadvantages. A good idea is also to demonstrate how RFID helps to make the job more efficient.
  RFID should be seen as a discharge from a lot of monotonous work and as an opportunity to establish the resources in another way.

5.2 Process

RFID needs to be put in context of its function within a company, and specifically its relationship and role within the information technology infrastructure. This is because RFID is a component of the system, and needs to work in harmony with other systems. It does not replace any of a company's core systems, but it may improve the performance and productivity.

Integration work needs to cover, but is not limited to:

- Systems design and engineering
  - Closed (accessible within a company)
  - Open (accessible between different companies)
- Systems integration (physical)
- Business process redesign and implementation
- IT data management integration (logical)

Other challenges with RFID to consider are:

- use of frequencies and power levels are regulated on regional level and in cases even within single countries
- difficulty with applying RFID tags in a consistent and reliable way to metal surfaces and fluids, hence currently limiting their application to cardboard, paper and plastic based packaging
- technology incompatibilities – meaning that interoperability between systems is not guaranteed
- reliability in reading tags and strategies to cope with the physically inescapable limitations
- tag characteristics
  - memory capacity
  - data transfer speed
  - read range
  - read of multiple tags
  - operating temperature

6 RFID Applications

At present a lot of companies have started a pilot RFID-Application, but until now there is no optimal best practice application existing. It is very important to emphasize, that each RFID application is individual, and has to be regarded in its own business environment

Within supply chains items are handled on multiple levels i.e. raw material, finished goods, spare parts. Shipments will occur between manufacturing sites, to distribution centers and to customers.

Business processes at each level may be unique but overlapping to a certain degree.

To enable interoperability within and between supply chains, standards need to be considered. Examples of standards that relate to this are:

- ISO 17363, Supply chain applications of RFID – Freight containers
- ISO 17364, Supply chain applications of RFID – Returnable transport items
- ISO 17365, Supply chain applications of RFID – Transport units
- ISO 17366, Supply chain applications of RFID – Product packaging
- ISO 17367, Supply chain applications of RFID – Product tagging

Annex 1: Regulatory Standards

The following list the regulation for use of RFID within Europe. Other regulations exist for other regions, defined by ITU.

ETSI TR 102 436, Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) intended for operation in the band 865 MHz to 868 MHz; Guidelines for the installation and commissioning of Radio Frequency Identification (RFID) equipment at UHF

ETSI TR 102 449, Telecommunications and Internet converged Services and Protocols for Advanced Networking (TISPAN); Overview of Radio Frequency Identification (RFID) Tags in the telecommunications industry

Annex 2: Technical Standards

ISO
18000-1 Part 1 – Generic Parameters for Air Interface for Globally Accepted Frequencies
18000-2 Part 2 – Parameters for Air Interface Communications below 135 kHz
18000-3 Part 3 - Parameters for Air Interface Communications at 13.56 MHz
18000-4 Part 4 - Parameters for Air Interface Communications at 2,45 GHz

18000-6 Part 6 – Parameters for Air Interface Communications at 860 to 960 MHz
18000-7 Part 7 – Parameters for Air Interface Communications at 433 MHz

RFID Data Protocol:
ISO/IEC 15961: Automatic identification and data capture – Radio frequency identification (RFID) for item management – Data protocol: application interface
ISO/IEC 15962: Information technology—Automatic identification and data capture techniques ----Radio frequency identification (RFID) for item management ---- Data protocol: data encoding rules and logical memory functions
ISO/IEC 15963: Automatic identification – Radio Frequency Identification for item management – Unique identification for RF tags;

Common Data Structures
ISO/IEC 15418 Information technology -- EAN/UCC Application Identifiers and Fact Data Identifiers and Maintenance
ISO/IEC 15434 Syntax for high capacity media
EPC Global Tag Data Standards version 1.3

Application standards:
ISO 17363 Supply chain applications of RFID -- Freight containers
ISO 17364 Supply chain applications of RFID -- Returnable transport items (RTIs)
ISO 17365 Supply chain applications of RFID -- Transport units
ISO 17366 Supply chain applications of RFID -- Product packaging
ISO 17367 Information technology -- Unique identifiers -- Part 4: Unique identifiers for supply chain management

Annex 3: Terminology / Abbreviations

Term	Description
ADC	Automatic Data Capture
ANS	American National Standards
Antenna	The antenna is the part of the system that radiates the RF energy to, and receives energy from the transponder (re. Fig 1)
BAR CODE	Linear code
CEN	Comité Européen de Normalisation, the European Committee for Standardisation.
EN	European Norm
ETSI	European Telecommunications Standards Institute
Frequency	The number of times a signal executes a complete excursion through its maximum and minimum values and returns to the same value (cycles).
IEC	International Electrotechnical Commission
ISO	International Standardisation Organisation.
Reader (Interrogator)	In an RF system, the device containing the digital electronics which triggers the transponder to respond, and extracts and validates the information from the transponder's modulated RF response (re. Fig. 4)
Transponder	An electronic TRANSmitter/resPONDER which is attached to the object to be identified and, when appropriate signals are received, transmits information as radio signals to a reader. (re. Fig. 1)